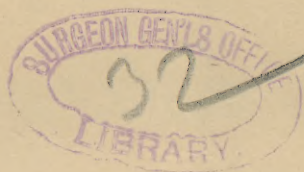


OSBORNE (J.W.)

on a new Meteorological  
instrument + +



OSBORNE (T.W.)

on a new Western  
instrument + +

---

---

ON A NEW  
METEOROLOGICAL INSTRUMENT.

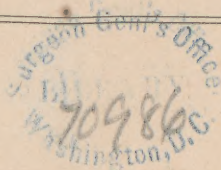
By J. W. OSBORNE,  
OF WASHINGTON, D. C.

---

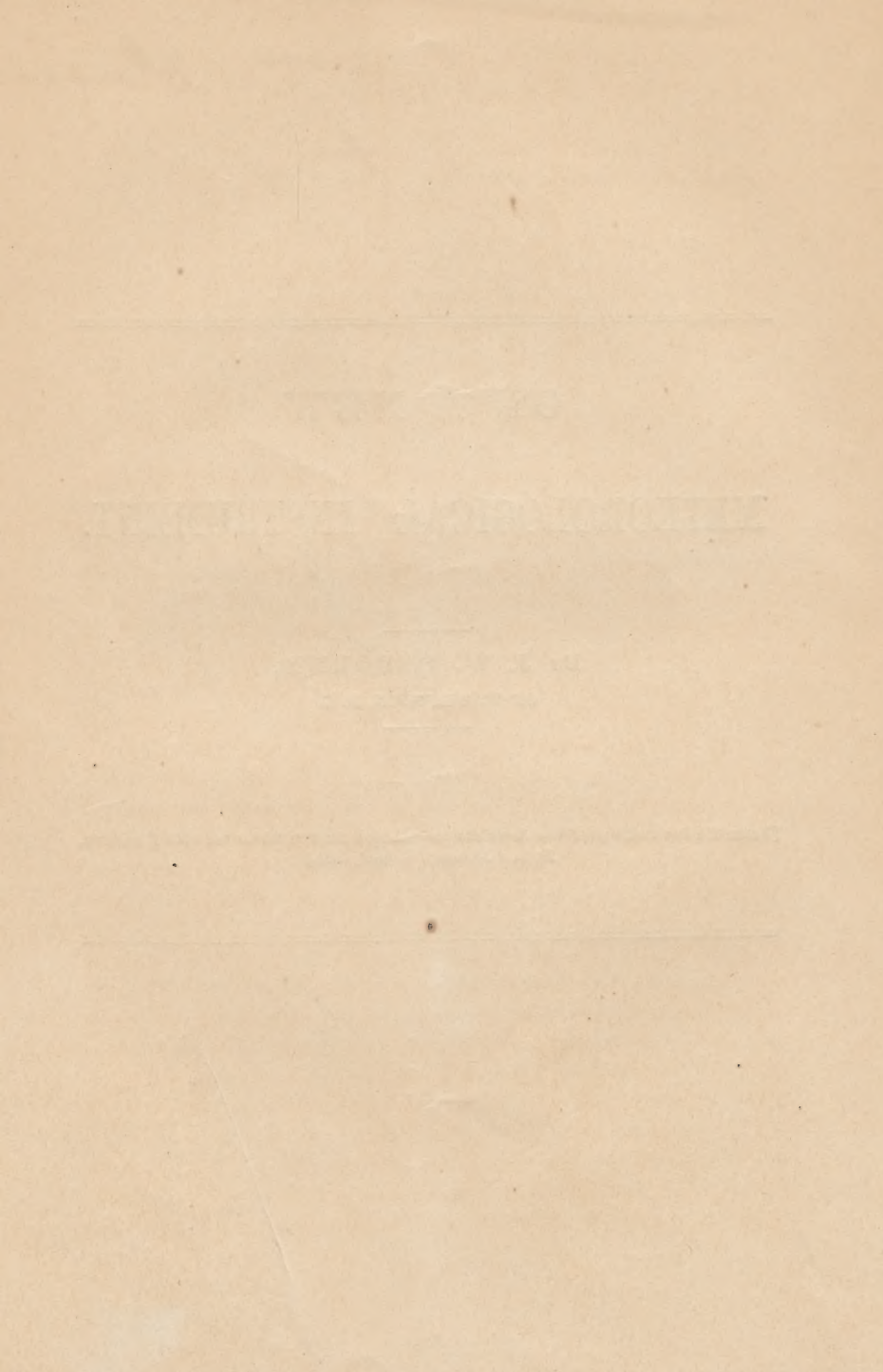
[From the Proceedings of the American Association for the Advancement of Science,  
Detroit Meeting, August, 1875.]

---

---



Box 52









ON A NEW METEOROLOGICAL INSTRUMENT. By J. W. OSBORNE, of  
Washington, D. C.

THE study of Meteorology has always possessed great attractions for those investigators who desire rapid practical results for the aid and benefit of mankind.

Of scientific men there has been a large proportion, both workers and theorizers, who have labored in this field; but it is chiefly of late years that great and important advances have been made. Not only have the means of observing atmospheric phenomena been improved, but the observations themselves have been systematically extended over vast tracts of country, and have, by the help of the telegraph, been collected with such rapidity, as to greatly increase their scientific as well as practical value. Great results have been the legitimate consequence of the large expenditures of labor and money which such records demand; results which have been appreciated by the general public, and still more thoroughly by scientific men; and which would now be very unwillingly dispensed with by either class. But it will be seen that these facts, however valuable and important, are all of an essentially objective character. We are informed both for the past and future respecting atmospheric pressure, and temperature; of the direction and force of the wind; of the relative quantity of moisture present, and of the amount of rain,—in a word, of all the available facts, external to the earth we stand on, and to our own bodies, which scientific and material resources can supply. These things have a bearing upon our comfort and prosperity; they affect

us as merchants, traders, agriculturists and manufacturers; and the information is conveyed in a form directly applicable to our wants; but we do not, procure from such statements, any distinct or precise knowledge of the manner or the degree in which they affect us personally.

It is hardly too much to assert that, at the present day, after years of laborious research, the meteorologists furnish no data from which it is possible to deduce the subjective character of any given climate, or its effect upon the human body. We might go farther and say—of life upon the face of the earth.

This is certainly true if we seek for a numerical expression which shall make possible the comparison of the climate of one place with that of another; or of the same place at different times of year; or the climate of indoors with that of the open air; for we cannot grasp in a single expression the several meteorological elements affecting us, referred as each is to a totally different unit of measurement. Considerations like the foregoing have caused me to attempt the construction of an instrument which would furnish the information sought, or such an approximation towards it, as would add definitely to our knowledge, and lay a foundation for future developments in this direction.

Confining myself at present to considerations affecting the human body, I will preface the description of the instrument itself, by drawing attention to the following facts.

If an effort is made to realize the nature of the influence which the elements exert upon the body of a man, it will appear that the prominent and leading effect they tend to bring about is a change in his temperature. This, for certain of the meteorological elements, may be either a raising or a lowering of the bodily heat; but taken together, their joint and total effect must tend at all times, and in every habitable climate, to dissipate and reduce the normal heat of the body.

If this were not so, the oxidation within the organism would cause an increase in the temperature of the blood and viscera, thereby establishing a state of things inconsistent with health, and with life itself, for any length of time. It must not be lost sight of, therefore, in considering this subject, that the body of a living healthy man is a mass of hot matter, cooling, and having its lost heat perpetually supplied by physiological changes, in quantity sufficient to maintain a uniform thermal standard of about  $98\frac{1}{2}^{\circ}$  F



And, whatever the causes of this loss may be, we say when it is rapid that the weather is cold, and when slow that it is hot. In the one case, the functions are called upon to make up the deficiency rapidly, and in the other to facilitate the dispersion of the body's superfluous and injurious warmth.

The temperature, as shown by the thermometer, is very commonly, I might almost say universally, accepted, as indicating the thermic influence acting upon us, and we speak of its readings as if they expressed in some way the sensible temperature with which the living organism has to deal. That this is an error, and a very pernicious one, a moment's reflection will serve to show. The day is hot and oppressive, if, at  $80^{\circ}$  F., the air is damp and still; while with a breeze and dry atmosphere, it is fresh and pleasant. Or, if in winter the thermometer fall to  $20^{\circ}$  F., no inconvenience is felt so long as it is perfectly still; but should it blow hard, then the cold will be almost unendurable.

Accordingly, what I shall call the physio-thermal effect, appears to be the joint result of several influences, acting simultaneously, each affecting in variable degrees, and often in contrary ways, the rate at which the body cools.

The three great factors which together determine the sensible climatic heat, are the temperature of the air at the time; the relative amount of aqueous vapour present; and the force or velocity of the wind. The first acts by accelerating or retarding, and sometimes altogether neutralizing radiation from the hot human body. The second, that is the moisture, promotes or hinders evaporation from the skin and lungs, in variable degrees, determining in like proportion the consequent loss of heat. The wind acts in two ways; first, as a convector, it removes from the body with greater or less rapidity the warmed film surrounding it, bringing cooler air in its place to be warmed up again in its turn; this action being of course reversed in those cases where the external temperature is above  $98\frac{1}{2}^{\circ}$  F.: and secondly, for a similar reason, the wind acts in all cases as a promoter of evaporation (except when perfectly saturated with moisture at or above the temperature of the surface of the body), the refrigeration bearing some relation to the rate at which it travels.

The problem I have sought to solve then is, to furnish means by the help of which we may express numerically and comparably that which hitherto has been left to vague conjecture and state-

ment, namely: the aggregate of the physio-thermic influences which affect the living human body at any particular time and place.

Without going into minute details, the instrument I have invented is constructed as follows.

A pole, or standard about six feet high, made of a strong brass tubing, is held upright by a heavy foot or base.

At right angles from this, and in the same direction, three arms or brackets extend. These, while they slide up and down on the standard, can be clamped at such places as suit the height of the observer.

The middle bracket is nine or ten inches long, and carries at its outer extremity a horizontal cylindrical ring of thin brass about four inches in diameter.

From the lower edge of this ring, and held fast to it by a strong rubber band or clamp-ring, there hangs a cylinder made of "bond," or bank-note paper. This cylinder is exactly 100 millimetres in diameter, and 150 long. It is made upon a turned mandrel, and closed up the side by the use of a thick mucilage of albumen, dried, and then coagulated by immersion in wet steam. This method gives a very narrow, strong seam, which absorbs water like the rest of the paper.

Into the open bottom of the paper cylinder a very thin disk of brass is fitted, and held there by a second rubber band or clamp-ring.

The vessel so constructed is intended to hold water. The paper which forms its walls can be removed and replaced at any time, without altering its capacity, or the relation between its bulk and surface. The upper edge of the brass ring, from which the paper cylinder hangs, is provided with a flat brass cap. Through the centre of this a short tube or socket extends. This revolves in the cap, fitting into a suitable bearing for that purpose. It terminates above in a small horizontal pulley, with a hole through its centre, while to its lower end an agitator is attached.

The agitator consists of a narrow strip of thin metal formed into a spiral, which makes four revolutions from the top to the bottom of the cylinder. When this is made to rotate, it sweeps the inside surface of the paper cylinder, but without touching it. From the brass disk below, three vertical stationary blades, placed radially, rise to the level of the top edge of the paper. These blades leave



still an unoccupied space in the centre of the cylinder; and between their outer edges and the paper, the spiral revolves freely. The object of the blades is to hold the water contained in the cylinder from revolving, so that the spiral, when in motion, may cause a constant current down the inside surface, and up the centre of the cylinder. The lower of the three brackets carries at its extremity an upright, adjustable, slender pin of wood, which fits easily into a little projecting socket attached to the centre of the under side of the disk, which forms the bottom of the cylinder, and prevents the paper suffering from lateral impulses given it by the wind, or when it is being moved from place to place.

The upper bracket carries a thermometer on its outer end. This is exactly over the axis of the cylinder, so that when it is lowered, the bulb, which extends seven or eight inches below the scale, passes through the horizontal pulley and short tube connecting it with the agitator, and takes its place in the centre of the mass of water, in which position it is clamped. This thermometer is provided with a centigrade scale. Its tube is ground flat, and polished on two opposite surfaces parallel to the ribbon of mercury. The scale to which it is attached is pierced by a narrow slit which extends from zero upwards to  $100^{\circ}$ . By this means I succeed in getting rid of the reflection from the cylindrical surface of the tube, and can watch the column of mercury as it appears projected against a little white screen adjustable behind the scale. A sliding cross hair parallel to the lines of division on the scale, and supported about an inch in front of the latter, is also used to fix the position of the eye when reading, and so avoid parallax. This slide is connected with a long screw at the side of the scale, by revolving which it can be placed and held in any required position.

For very exact readings a microscope with cross hair is also employed, which then takes the place of the simple slide just described.

A clock-work, attached to the standard below the brackets, imparts motion to a small silken belt which runs upwards in a vertical plane as far as the middle bracket, where two little rollers give it a lateral direction, so as to drive the horizontal agitator-pulley, and thereby keep the contents of the cylinder in a thoroughly mixed and moving condition, that the temperature of any part may be always that of the whole.

Below the clock-work a vessel of thin brass is supported by a

short arm. This is somewhat larger in size than the paper cylinder ; it fills a double purpose, acting as a covering for the cylinder when not in use, and receiving the overflow water from it in a manner to be presently described.

A fourth bracket or arm, which may be regarded as supplemental to the instrument proper, is clamped at a convenient height on the central standard. It extends in an opposite direction from the other three, and carries the ordinary wet and dry bulb thermometers, and a stop watch with a spring-back second hand.<sup>1</sup>

Lastly ; a high copper vessel called the filler, holding about two quarts of water, with a long curved spout tapering down to  $\frac{1}{4}$  inch diameter, is used for filling the cylinder with hot water.

This filler is furnished with a cover, and a wooden handle opposite the spout ; it is also provided with a thermometer which is slipped into a small dry tube extending from the top obliquely towards the centre of the vessel, so that while the water in it is heating on a gas stove, its temperature can at any time be ascertained approximately.

I proceed now to explain the way in which observations are taken with this instrument. The cylinder above described is a porous vessel. Its bond paper walls are slowly permeable to water, so that without appearing wet on the outside, they offer to the air as much moisture as it is capable of taking up ; that which is lost being quickly replaced by capillary action. Experiment so far has shown this to be the case, except when the evaporation is very excessive indeed. The bond paper by its strength, and the purity of its composition, and from the fact that it can be obtained of perfectly uniform character, is admirably adapted for this purpose ; and when wet it looks and feels very like an animal membrane. I know of no material of constant quality, and one which could be made into a vessel of a definite and fixed size, that would answer as a substitute for it.

If the suspended cylinder so constructed be filled with water at the temperature of the blood, it will be seen that its condition is similar to that of a man who has lost the power of generating

<sup>1</sup> In the drawing which accompanies this paper, two stop-watches are shown instead of one, by which the timing of sequent intervals is much facilitated. Both watches are connected by a brass strap in such a way that the movement which stops one starts the other instantly. The spring-back arrangement is independent of this, so that each reading is made from zero, with plenty of time for its exact registration.



heat. Both will instantly begin to fall in temperature. Now if we could ascertain the time in which the man's body fell one degree, we would be justified in assuming that when he was in the normal condition he would have had to make the same amount of heat in a like interval, inasmuch as he always has to make exactly what is lost.

Strictly speaking, a little more would be demanded of him, because the hotter his body is, the more heat he will lose in a given time. For very small increments however, this difference may be neglected, and I will not at present discuss it.

This interval of time then, would express the demand upon the system, the intensity of the physiological action necessary to sustain the body in a state of health; and it would also be a measure of the climate at that particular time and place, subjectively considered. As such a determination for the actual man is impossible at present, I endeavor to obtain a comparable result from the cylinder. Assuming it to be full of cold water, as is generally the case, its temperature is raised by slipping a piece of small rubber tubing over the spout of the filler, the contents of which have been previously heated several degrees above blood-heat, and attaching the other end of it to a little conical tube which passes through the thin brass disk, forming the bottom of the cylinder. This tube is flush on the inside, and is closed there by a small flap of thin rubber, so that the water cannot flow outwards. By raising the filler above the level of the top of the cylinder, the hot water lifts the valve and enters. As it rises, it fills a small siphon tube, which passes through the side of the brass ring from which the paper hangs, and then flows off through a rubber tube to the overflow vessel, near the foot of the standard, which has been already described.

At the commencement of this operation the clock-work is set in motion, whereby the agitator is made to rotate, and establish so perfect a mixing of the hot and cold water as to cause the temperature to rise gradually and steadily; the addition of hot water can then be checked, and the rubber tube removed, at any particular position of the mercury. After this has been done, the siphon still continues to act, until the water is finally cut off exactly at the upper edge of the paper, by which the quantity of water in the cylinder is always precisely the same.

Having raised the temperature of the whole mass of water dis-

tinently above blood-heat ( $37^{\circ}\text{C.}$ ), and letting the agitator continue uninterruptedly, the observer waits till the mercury falls to  $37^{\circ}\text{C.}$ , when he starts the stop watch, and counts the time in seconds which each degree takes to fall, till he has obtained a series sufficiently long to give the character of the descent, and render a reduction to a single expression possible. In summer weather about six readings will probably be found sufficient; in winter a greater number may often be desirable. The whole interval which elapses from first to last, should be long enough to allow of several repetitions of the cycle of fluctuations in the thermic influences, which the observer will soon recognize, so that an average result may be had. When a series of this kind is made under constant conditions (as for instance in a closed room) a perfectly smooth and regular curve will be the result; but this is not easily obtained, because of the difficulty of maintaining such conditions perfectly. In the open air the changes in the velocity of the wind invariably give rise to irregularities with which the mathematician will have to deal. These irregular oscillations coincide exactly with the gusts of wind, and the comparatively still intervals between them; they coincide also with the observer's sensations of coolness and warmth.

The general character of these curves is much influenced by the position of the wet bulb temperature in relation to  $37^{\circ}\text{C.}$  When these are near each other, the cylinder will cool slowly, and the curve will be flat; when the temperature of evaporation is low, the fall will be rapid, and the curve proportionately steep. That this must be so will be recognized at once, when it is remembered that the ordinate coinciding with the temperature of the wet bulb must be regarded as an asymptote to the curve.

No earnest attempt has yet been made to determine the equation of these curves. Indeed there has not been time, nor a sufficient number of satisfactory observations made under constant conditions; but as an expedient for present use and instruction, I devised the following method, by which to obtain comparable reductions which should furnish values proportional to each other.

If, under constant influences we extend the readings upwards from  $37^{\circ}\text{C.}$ , beginning to time the fall of the thermometer at say  $60^{\circ}\text{C.}$ , we shall find that the curve at such high temperatures differs very little from a straight line.

If we regard it as such, and select say  $50^{\circ}\text{C.}$ , as the point of

comparison, we shall obtain readings from which it is easy to eliminate the irregularities due to wind, or any other intermittent causes. Thus, if the day is very warm the observer begins to time the descending mercury at  $53^{\circ}$  C., and counting till it reaches  $3^{\circ}$  below 50, namely  $47^{\circ}$  C., he divides the total number of seconds by 6. This interval in the hottest and most sultry weather will be about 5 minutes. If the day is cooler, judging by his feelings, the observer may fix on  $4^{\circ}$  above and  $4^{\circ}$  below dividing by 8; if quite cold  $10^{\circ}$  above, and  $10^{\circ}$  below, and even double that will not be too much, always aiming at a total interval of about 5 minutes.

It will be seen that the colder the weather is, the more nearly will the curve about  $50^{\circ}$  C. approach a straight line, and the further below that temperature will it retain the same character, so that the error will not increase with the longer distance travelled by the mercury. This method is based upon the assumption that the ordinates of the normal curve are proportional, and that an arithmetical mean will therefore reduce them, however irregular, to a single expression.

It may be urged that results so obtained are disassociated from the blood temperature with which we started; but it should not be forgotten that we do not aim to get absolute, or even relative values. The great difference in men's weight, and surface in relation to their weight; in the amount of clothing they employ; in their habits of body, and in many other ways, renders that impossible. All we can hope for are results which shall be themselves proportional, and comparable only as regards the average man.

With this in view one temperature is theoretically as good as another, although in the practical use of the instrument, and in the application of corrections, which have yet to be investigated, a judicious selection may be made. Nor should it be thought that I regard the observations at high temperatures, as replacing the series at low ones, which give us the special character and fluctuations of the thermic influences. The latter are of the greatest importance, and throw much light both on the nature of the climate, and on the physiological power of resistance to its influence, which the body is called upon to exert. In this connection it may be well to say something of the dimensions given for the present to the cooling vessel. Numerous experiments have been made with cylinders of different capacity, and with large differences in the relation of mass to surface. The result reached appears to

be tolerably satisfactory and serviceable ; but it cannot be regarded as fixed ; nor is it possible by *a priori* reasoning to establish any size as the best. The conditions to be kept in view are, first :— To see that the rate of cooling is not disproportionately influenced by any one of the three factors. Second : to give the cylinder sufficient mass to ensure readings of suitable duration. Third : to make the instrument as a whole convenient and manageable, in a mechanical sense. To discuss this subject fully, more information is required than I possess at present.

Having done something towards arriving at a knowledge of the aggregate of physio-thermic influences which the temperature of the air, its moisture, and its motion jointly exert ; our next effort should be to analyze that aggregate, if possible, and apportion to each factor its share, positive or negative as the case may be, in the abstraction of animal heat.

If we observe with two cylinders at the same time, which are identical in every respect, save that one is pervious, and the other impervious to water, the results will differ, that from which there is no evaporation taking longer to cool than the other. This difference will express the value of the aqueous vapor present, as a cooling agent.

If simultaneous observations are made with two instruments, one exposed to the full force of the wind, and the other sheltered from it, but otherwise under the same conditions, we shall in like manner get an expression of the thermic influence referable to the wind, both as a convector and as a promoter of evaporation.

If both cylinders are impervious to water we shall again eliminate evaporation and obtain the cooling effect of the dry air in motion.

If from the aggregate effect of all the factors, we now deduct that due to the moisture, and to the wind, the remainder will be the thermic influence ascribable to the actual temperature alone.

There may be, and doubtless are, many and serious difficulties to be overcome in making these determinations ; but that the knowledge I have indicated in the foregoing, will eventually be obtained, there is little doubt, as there can be none of its great importance and value to mankind.

One step more it will then be fair to demand ; I mean the discovery of empirical formulæ, by which meteorological observations already made and recorded may be converted into expressions of



thermic influence. In this way a vast flood of light will be quickly thrown on questions relating to the influence of climate on conditions of health and disease; development and decay; mental energy; and subjects of like immediate personal interest.

To speak of results at this time, and obtained from an instrument but a few months in existence, would certainly seem premature; and yet some things have been so forcibly presented to my mind, that a very short statement of them may be permitted. The consecutive, outdoor observations I have made consisted of two daily, at 7.35 A. M., and at 4.35 P. M., synchronous with those of the signal service observatory. These have been prosecuted for a little more than two months.

The deductions which they certainly justify are as follows:—

1. That the sensible temperature affecting us departs widely from the actual, obtained from the thermometer.

2. That the fluctuations in it are infinitely greater in amount than most of us have any idea of.

3. That besides the great changes from day to day in the mean sensible temperature, we have what may be called instantaneous oscillations, also very considerable in amount, and scientifically all but unknown.

4. That the wind very often plays a more important part in determining the sensible temperature than the actual temperature itself.

5. That the instantaneous oscillations are almost solely due to fluctuations in this meteorological element.

The first statement I have already illustrated by an example, which might be supplemented by a multitude of others; for nothing is more common, while the thermometer is always quoted as something which cannot err, than to hear people praise or blame the weather quite irrespective of the teachings of that instrument, and often in direct contradiction to them. We use in fact in ordinary conversation a number of phrases which show the necessity in the popular mind of qualifying the information furnished by science. We speak of hot weather as sultry, close, heavy, dull, muggy, and clammy; or as fresh, pleasant, and clear. Of the cold days as raw, bitter, or damp, and also as fresh, bright, and invigorating.

We describe a locality as exposed and bleak; or as sheltered and warm. A house as drafty; a street as “shut in.” We say

that not a breath of air is stirring ; meaning really that we feel the want of some cooling agent, and for relief we fan ourselves to "get air." All such qualifying words give vague expression to phenomena which figures do not reach.

With regard to the wide range of the sensible temperature it may be said that the difference in the rate at which we lose heat, on a still, hot, and moist day in August or September, and on a cold one in midwinter, with the mercury below zero, and a gale of wind blowing, is very great indeed, subjecting the bodies of all exposed animals to extremes of heat and cold of which the physiologists have taken but little account. Still less have they recognized the existence of instantaneous oscillations. As we sit in our rooms, every breath of air which enters lowers the sensible temperature, and every moment of calm raises it immensely ; an incessant rise and fall which may take place several times a minute.

To illustrate the importance of the wind as a thermic agent, the assertion may be ventured, that there are many wet, stormy climates, such as that of Ireland, where it scarcely freezes, that will be found, so far as our bodies are concerned, to approach the still, cold climate of the icy north.

In the foregoing I have made no reference to the direct, radiant heat from the sun ; nor has anything been said of the thermic influence on vegetable life. These subjects are of very great importance, but their discussion can perhaps be better undertaken at a future time.

It should not be thought that in pursuing the present inquiry, I have ignored the other influences which climate exerts upon man ; acknowledging those only that manifest themselves by sensations of heat or cold. This is not the case ; but I do maintain that such appear to our present view as by far the most important, as well as the most amenable to investigation.

I earnestly desire the coöperation of others in developing the untrodden field which forms the subject of this paper. Everything in my power which can aid any one wishing to prosecute similar observations, shall be done with the utmost heartiness. Work of this sort is arduous and exacting, and until it is taken up by many persons, its progress will be slower than its importance demands.



